Risk assessment for *Toxoplasma gondii* in the Danish pig industry

Boes, J.*[(1)], Alban, L.[(1)], Sørensen, L.L.[(2)], Nersting, L.[(3)]

Danish Meat Association, [(1)]Vinkelvej 11, DK-8620 Kjellerup, [(2)]Axeltorv 3, DK-1609 Copenhagen, [(3)]Maglegårdsvej 2, DK-4000 Roskilde, DENMARK
* *Jaap Boes: jbo@danishmeat.dk*

Abstract
The parasite *Toxoplasma gondii* is capable of infecting most mammals including man. In humans, toxoplasmosis is usually asymptomatic but may have serious consequences for pregnant women or immuno-compromised patients. Contact with infected cats and cat litter, contaminated soil and infected meat are risk factors for toxoplasmosis. Although the prevalence of *Toxoplasma* in pig production has declined significantly during the past 30 years, it has recently been suggested that a large part of human cases of toxoplasmosis may be ascribed to meat, including pork and pork products. Moreover, perinatal screening of pregnant women and infants for *Toxoplasma* has proven to be of limited value. This has raised the question of how to survey for *Toxoplasma*: in humans or meat? Therefore, the role of meat, including pigs and pork, as a risk factor for human toxoplasmosis was assessed by the Danish Meat Association. The release assessment showed that outdoor-reared pigs as well as sows and boars were at higher risk of infection with *Toxoplasma*. With respect to exposure, consumption of mildly cured pork products and inadequately heat-treated pork were associated with increased risk. Knowledge on elimination or survival of *Toxoplasma* in cured pork products is sparse, which is unsatisfactory given current trends toward lower salt content and lower cooking temperatures. It was concluded that, aside from consumption of raw pork, which is rare in Denmark and not recommended for other reasons, certain mildly cured ready-to-eat pork products, that have not been heat-treated, may constitute a risk for toxoplasmosis, if not frozen prior to manufacturing. Information on the effects of curing on survival of *Toxoplasma* in meat is sparse and therefore deserves further research. However, most of the pork used for manufacturing in Denmark originates from pigs raised indoors and for logistic reasons it is frozen prior to processing, thereby reducing the risk for human toxoplasmosis.

Introduction
Toxoplasma gondii is a ubiquitous protozoan parasite that can infect most mammals, including man. The main sources of infection for humans are contact with infected cats or cat litter, contaminated soil or ingestion of undercooked infected meat. The prevalence of *Toxoplasma* in pig production has declined significantly during the past 30 years, and especially in finisher pigs raised indoors seroprevalences are now typically below 5% (see Tenter et al., 2000, for review). This decline is mainly attributed to more intensive housing systems especially in Europe and hence reduced exposure to *Toxoplasma* from cats and the environment (Tenter et al., 2000).

However, recently a European multi-centre study on *Toxoplasma* has suggested that 30-60% of human cases of toxoplasmosis may be ascribed to meat, including pork and pork products, albeit with substantial variation between centres as regards the type of meat involved (Cook et al., 2000). Other studies have also indicated an association between the risk of acquiring *Toxoplasma* and consumption of undercooked pork or certain cured pork products (e.g. Buffolano et al., 1996; Kapperud et al., 1996). However, the question remains: what is the role of meat, and in particular pork, for human toxoplasmosis?

To address this question, a risk assessment was conducted by the Danish Meat Association. The aim was to assess the risk for human toxoplasmosis associated with pork and pork products. The risk assessment followed the guidelines issued by Codex Alimentarius and OIE and contained the following steps:

- Hazard identification
- Release assessment
- Exposure assessment
- Consequence assessment
- Risk estimation

Finally, we provide some suggestions for risk management.

Hazard identification

Toxoplasma is, amongst others, a meat-borne infection that can cause serious disease in unborn children or immuno-suppressed patients. Like in many other European countries with intensive pig production, *Toxoplasma* is found at a low prevalence (3%) in Danish finisher pigs (Lind et al., 1994). However, it cannot be excluded that some cases of human toxoplasmosis in Denmark can be ascribed to pork. Therefore, *Toxoplasma* was considered a relevant hazard.

Release assessment

To date, serology is the quickest and most-often used method of testing pigs for *Toxoplasma*, being a good indicator for the burden of *Toxoplasma* in a pig (Dubey et al., 1995). *Toxoplasma* seroprevalence in pigs in Europe is generally low (i.e. ≤5%) in finisher pigs that are raised indoors. Higher prevalences have been found in outdoor-reared pigs (Fehlhaber et al., 2003; Kijlstra et al., 2004; Venturini et al., 2004), and the highest prevalences are found in sows and boars (Tenter et al., 2000).

Exposure assessment

Due to expensive bioassay methods and not yet validated DNA methods, only limited data exist on occurrence of *Toxoplasma* in raw, unprocessed pork. Evidence stems largely from human case-control studies showing that toxoplasmosis might be associated with, amongst others, consumption of raw pork (e.g. Cook et al., 2000). In a recent comprehensive study, Dubey et al. (2005) found *Toxoplasma* in 0.4% of 2,094 fresh pork samples purchased in retail outlets in the US.

Toxoplasma in pork will survive refrigeration at 4°C but not at 0°C (Hill et al., 2006). *Toxoplasma* does not multiply in fresh or refrigerated meat. Processing methods with a well-documented effect of eliminating *Toxoplasma* in meat are freezing and heat-treatment (cooking, frying). Freezing at –12°C for 24 hours (e.g. Kotula et al., 1991; Smith, 1991), or heating to a core temperature of 61°C for at least 1 minute (e.g. Dubey et al., 1990; Dubey, 2000) will inactivate *Toxoplasma*. In addition, *Toxoplasma* tissue cysts can be eliminated using radiation techniques (Smith, 2001) or high-pressure processing (Lindsay et al., 2006).

In contrast, knowledge on elimination or survival of *Toxoplasma* in cured pork products (salted, smoked, dried or fermented meat) is sparse. This is unsatisfactory given current trends toward lower salt content and lower cooking temperatures. Among curing procedures, the effect of salting is best-documented. Salt concentrations of ≥6% eliminate *Toxoplasma* in pork, whereas *Toxoplasma* may survive at lower salt concentrations (Dubey, 1997). Curing of pork loins with 2% sodium chlorate or ≥1.4% potassium or sodium lactate for at least 8 hours prevented transmission to cats (Hill et al., 2004; Hill et al., 2006).

The very few studies that looked at survival of *Toxoplasma* in dried, smoked and/or fermented pork did not detect viable *Toxoplasma* (Sommer et al., 1965; Warnekulasuriya et al., 1998).

Consequence assessment

Seronegative pregnant women and immuno-compromised patients are the main risk groups for toxoplasmosis. Depending on the time of infection, congenital *Toxoplasma* infection may result in abortions or birth of infants with clinical signs (transmission during early pregnancy) or birth of infants with subclinical infections, resulting in nervous disorders or eye problems later in life (transmission during late pregnancy). Immuno-suppressed patients (e.g. AIDS patients) may show severe clinical symptoms such as encephalitis.

Risk estimation

Humans: Toxoplasmosis has serious consequences for pregnant women without immunity to *Toxoplasma*, because both foetus and newborn children may be affected. From 1992 to 1996, the incidence of congenital toxoplasmosis in Denmark was 3 per 10.000 newborn infants. The proportion of newly acquired *Toxoplasma* infections in pregnant women that can be ascribed to pork is unknown, as is the infective dose for congenital toxoplasmosis.

Pigs: In Denmark, the prevalence of *Toxoplasma* was 3% in finishers and 12% in sows (Lind et al., 1994). *Toxoplasma* prevalence in outdoor-reared pigs in Denmark is presently unknown, but other studies have shown a higher prevalence compared to indoor pig production. This suggests that sows and outdoor-reared pigs constitute a higher risk for human toxoplasmosis. On the other hand, the bulk of pork produced in Denmark originates from finishers, not sows, while pork from outdoor-reared pigs in Denmark constitutes less than 1% of the total production.

Pork: No data are available for *Toxoplasma* in fresh pork in Denmark. *Toxoplasma* in meat will remain infective during refrigeration. On the other hand, if pork is sufficiently frozen before/heated during preparation, then the probability of *Toxoplasma* infection is negligible (see Table 1).

Processing: Aside from consumption of raw or undercooked meat, possible risk products for *Toxoplasma* are certain ready-to-eat pork products that have not been heat-treated and/or contain low levels of salt. Examples are smoked filet, smoked ham and some naturally fermented fresh sausages, but not dry-cured sausages (Table 1). In theory, the risk for human toxoplasmosis will increase if risk products are produced using meat from sows or outdoor reared pigs. However, both production and consumption of risk products manufactured with e.g. meat from outdoor reared pigs is limited in Denmark, suggesting that this is of minor importance.

Table 1:
The effect of meat processing on survival of *Toxoplasma gondii* in pork and pork products

Product type	**Effect on *Toxoplasma***	**Risk product**
Fresh pork Minced pork Raw sausage, marinated meat	Eliminated by heat treatment* or freezing	Insufficiently heat-treated meat
Bacon		Raw bacon
Cured meat products (salted, not heat treated, ready-to-eat)	May survive; no multiplication Elimination if the meat is frozen prior to processing	All mildly-cured products from meat that has not been frozen prior to processing
Fermented sausage, salami	Probably eliminated (high salt content)	Probably none
Pasteurised meat products Ready-to-eat products (heat treated) Conserves (canned meat)	Eliminated	None

* To a core temperature of at least 61°C for 1 min.

Risk management

Our assessment shows that occurrence of *Toxoplasma* in confined finishing pigs reared in modern industrialized farms is very low, and that most of the pork is processed in ways that will eliminate *Toxoplasma*. Therefore, from a cost-effectiveness point of view, risk management for *Toxoplasma* should not focus on release (pigs) but on exposure (pork).

There are several ways to reduce the risk of exposure to *Toxoplasma*. Firstly, proper processing by use of freezing, heat-treatment or effective curing will reduce exposure through meat. For example, it could be recommended not to use meat from sows or outdoor reared pigs for risk products, unless the meat has been frozen. Secondly, information campaigns directed at pregnant women can be a very effective means of focusing on ways to reduce exposure to sources of *Toxoplasma*. These campaigns should include advice on not only to avoid consumption of raw or undercooked meat, but also to avoid contact to cat litter and soil, as well as maintaining good kitchen hygiene. A

third option, suggested by several authors, would be labelling of risk products, in line with the labelling of certain French soft cheeses that contain a message to pregnant women about the risk of *Listeria* infection.

Conclusions

It was concluded that, aside from consumption of raw pork, which is rare in Denmark and not recommended for other reasons, certain ready-to-eat pork products, that have not been heat-treated, may constitute a risk for toxoplasmosis, if not frozen prior to manufacturing. Information on the effects of curing on survival of *Toxoplasma* in meat is sparse and therefore deserves further research. However, most of the pork used for manufacturing in Denmark originates from pigs raised indoors and for logistic reasons it is frozen prior to processing, thereby reducing the risk for human toxoplasmosis.

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